Feb. 8, 1938. C. E. VAN STONE 2,107,457

APPARATUS FOR MAKING CASING AND FORMATION TESTS IN WELLS

Filed June 15, 1936 2 Sheets-Sheet 1

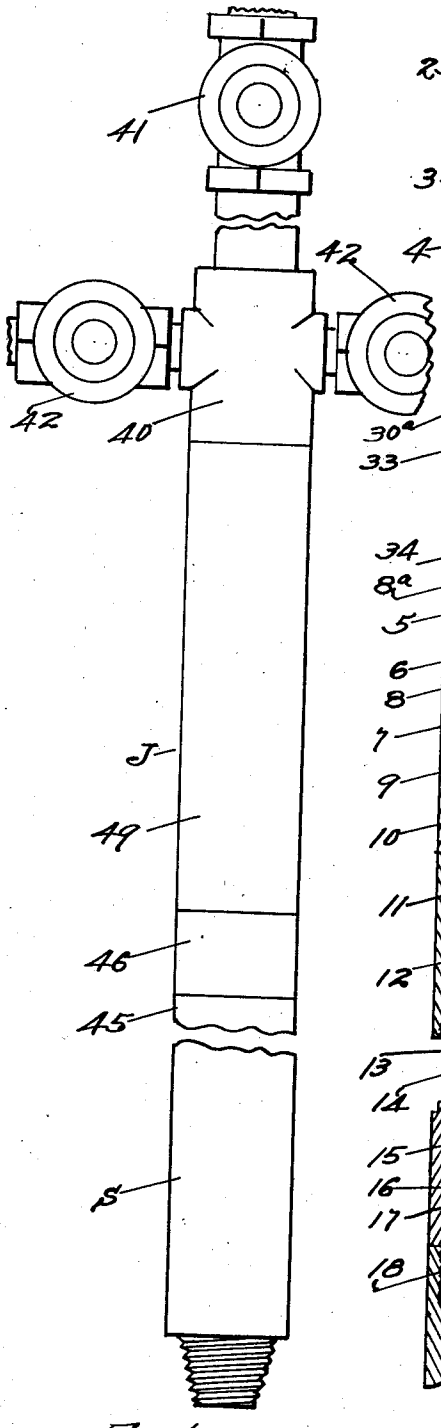


Fig. 1

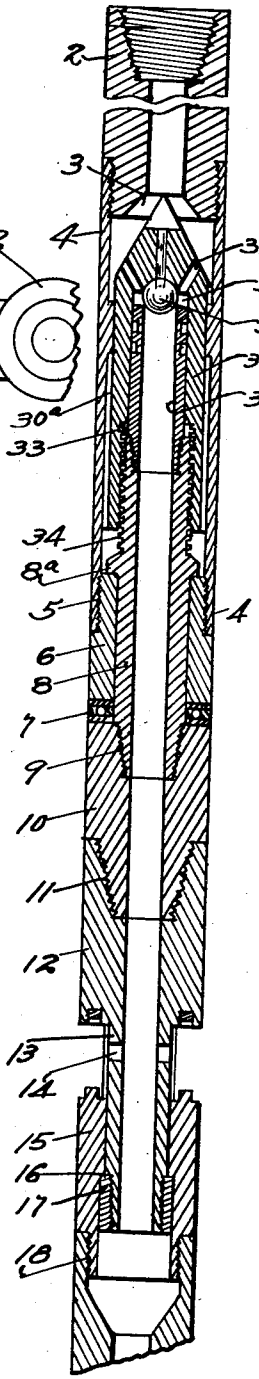


Fig. 1a

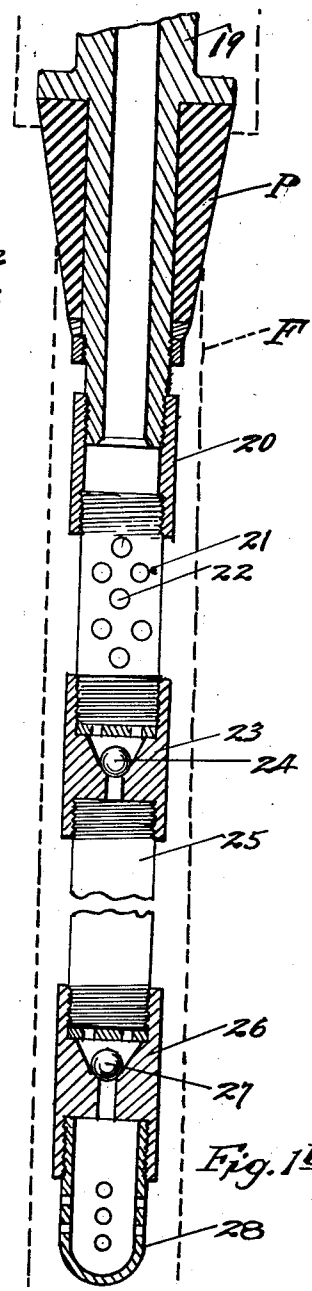


Fig. 1b

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Feb. 8, 1938. C. E. VAN STONE 2,107,457

APPARATUS FOR MAKING CASING AND FORMATION TESTS IN WELLS

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Fig. 2.

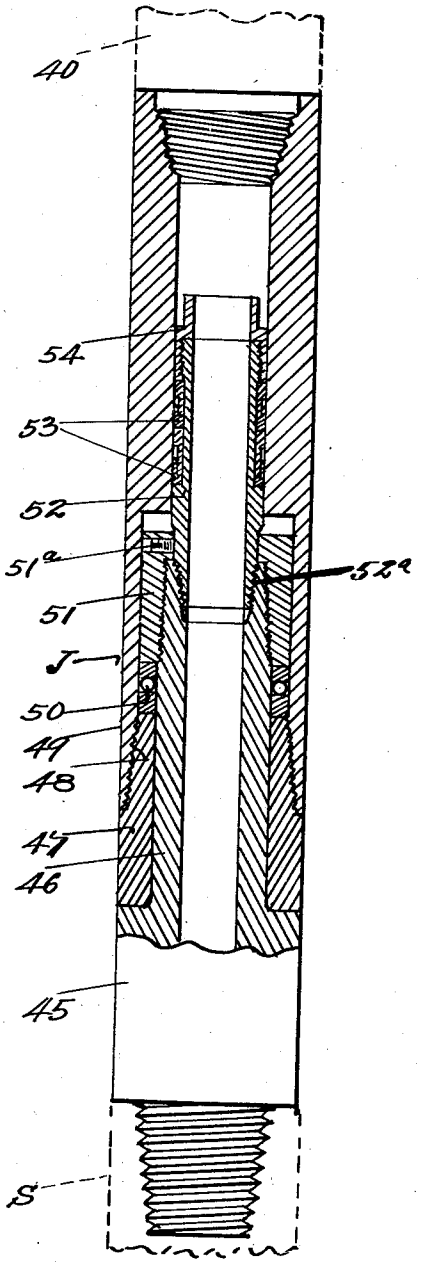
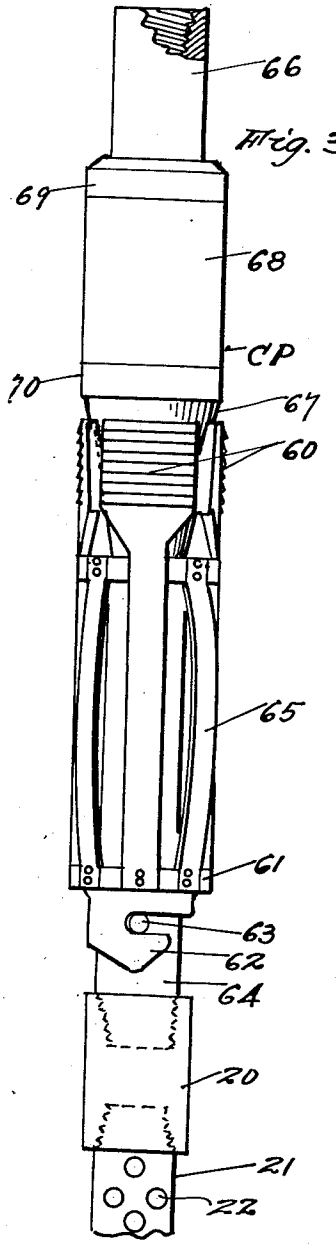


Fig. 3.



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Patented Feb. 8, 1938 2,107,457

UNITED STATES PATENT OFFICE

2,107,457

APPARATUS FOR MAKING CASING AND FORMATION TESTS IN WELLS

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Application June 15, 1936, Serial No. 85,187

15 Claims. (Cl. 166—1)

This invention is a method and apparatus for safely making tests of the fluid which may be present at one or another levels in various wells, more especially deep, drilled oil wells, by entrapping a specimen of the fluid at the desired level, and is, further, a method and apparatus for controlling and regulating flow of the well and, if need be, for killing the well.

The apparatus is kindred to that shown in U. S. Patent No. 263,330, issued to Benjamin Franklin, August 29, 1882, where there is shown a device having a valve "which will close the tubing while it is being drawn", page 1, line 35, and the patent states that this device is connected in the tubing "at a point above the packer", line 17, page 1. Packers were well known in the art, then, at the time of Franklin's device for "controlling and regulating the flow of oil wells". Franklin thus disclosed he could control the well and that he could close the valve at the bottom of the well and then draw the tubing and its closed valve. He states that it was old to put a dry pipe down a hole by use of a breakable disc, but the objection was that it would not close the tube while drawing it. His device was intended to permit the tube to be lowered dry or empty above the valve, the valve then to be opened for any desired period for the admission of the well fluid from below the packer, and then closed when the device is withdrawn so "that no flow can take place through it", page 1, line 25. If the well flowed to the head the rate could be controlled by the valve; if the hole was dry the string was pullable with the valve open or closed, if it happened that the formation fluid flow did not have natural pressure enough to flow to the head but did rise above the valve, then when Franklin closed the valve before withdrawing the "device", according to his expressed operation, he would have entrapped the fluid present above the valve.

An object of the invention is to provide a method and apparatus in this art having many advantages over previous methods and apparatus.

A purpose is to provide a testing apparatus including a tubular string, having a master valve, readily adaptable to seal off upper and lower portions of a well hole whether having a cemented casing or not, to determine the nature of the fluid below the packed off level in the well hole, or in cemented casing, as the case might be, and to provide an uncontaminated specimen trapping compartment or barrel at the lowermost portion of the testing string capable of holding the specimen regardless of whether the master valve may be in open or in closed position while the string is being withdrawn from the well hole, if necessary, to provide for removal of the specimen from the trapping barrel for its examination.

Further, an object is to provide a testing and control string including a packer and a specimen trapping barrel therebelow to facilitate the entrapping of well formation products or fluid closest to the bottom of the hole or, in cases of water test for cemented casing, to take a sample of the water, if any, immediately below the end of the set casing.

Another object is to provide valve means to maintain a dry string while lowering in and which will control the admission of the formation or other fluid to the trapping barrel after the packing device of the string has been set on formation, or on casing, and which valve means is operative, without effect on the loaded barrel, to allow the well fluid to flow upward in the string and then to shut off the up flow or to close the string thereat so that a second volume of the well fluid may be trapped apart from the specimen collected in and by the foot barrel, though all of the entrapped fluid may rise through the barrel.

In some cases of well testing it is desirable to have full control of the testing string and the well in addition to the control afforded by the above mentioned master valve which is incorporated in the lower parts assemblage. To that end the apparatus includes the combination with the upper string parts of a head works appliance including control valves associated with desired flow lines and, if desired with a high pressure source, having a control valve, and, in such a combination, to provide for the free relative operation of the subjoined string apparatus to open or to close the master valve of the trapping barrel, as by the inclusion of a swivel joint between the string forming the testing tool and the head works alluded to just above. Thus provision is made for making the desired test under full control and without danger of blowout or undue velocity of flow with its incidental injurious effect on the mechanism of the apparatus.

In making a casing, water shut-off test if the hydrostatic head of well water about the casing is suddenly thrown unbalanced onto the casing there is danger of fracture thereof and of opening leaks at the cement seal and an object of

this invention is to provide a testing string having means whereby to perfectly control the rate of admission of unbalanced well fluid as it enters the trapping barrel, in cases where the test shows that the cement is not making a shut-off.

A purpose is to provide a testing tool or string including a by-pass means for water level equalization between points above and below the packer seal and to provide a master valve which may be opened to the by-pass to effect a "dry job" extraction of the string without loss of the desired and entrapped well specimen, whether formation product or water-test liquid at a cemented pipe.

An additional purpose of the invention is to provide a testing string valve having dual closing positions in the assembly and to provide for the moving of the valve from one position of closing relation to an intermediate or open position, and then to another closing position all by a single directional movement of the operating string.

The invention consists in certain method and mechanical advancements in this art as set forth in the ensuing disclosure and, having, with the above, additional objects and advantages as hereinafter developed, and whose construction, combination and details, and manner of operation and the several steps of the method will be made manifest in the description of the herewith illustrative embodiment; it being understood that modifications, variations, and adaptations may be resorted to within the scope, principle and spirit of the invention as it is hereinafter more directly claimed.

Figure 1 is an elevation of the upper portion of the apparatus.

Figure 1*a* is an axial section of a portion of the tool string showing the control valve in its lower closed position and showing the by-pass joint in open position, and Figure 1*b* is an axial section of the trapping, foot section.

Figure 2 is an axial, detail section of the swivel joint of the well head attachment.

Figure 3 is an elevation of a conventional casing packer applicable to the testing string for making a casing water shut-off test.

It is understood that hereinafter the term "testing" and other terms referring to testing apparatus are intended to broadly include all types of testing for well fluid specimens in drilled well holes since the principal features of the method and apparatus are available for such jobs by mere application of appropriate packers, that is, a rat-hole packer, or a hole wall packer, or a casing packer; these types being adapted for the special service according to the given job.

As shown in Fig. 1, a tubular or drill string S (of any number of joined sections) attaches to a connector **2** which is connected to or provided with an inverted valve seat **3**. To the seat section is screwed a shell **4** whose lower end is screwed at **5** onto a bushing **6** at the lower end of which there is an antifriction bearing **7** circling a hollow core **8** which swivels in the bushing **6** and screws at **9** into a pin coupling **10**. This coupling screws at **11** into the upper end of a telescoping joint section **12** having an axial nipple **13** provided with upper by-pass or bleeder ports **14**, and being splined in a jacket **15**.

The joint nipple is shown in open position so that well fluid may pass into or from the nipple passage. When the nipple is lowered into the complementary jacket the ports **14** will be covered and flow of fluid therethrough stopped.

The joint jacket **15** is internally shouldered at **16** to receive an opposing shoulder **17** on the nipple to limit opening movement of the ported nipple and, further, to form a suspending connection between the nipple and the jacket so that the latter will bear the subjoined string assembly.

In the packer adaptation, the jacket **15** is screwed at **18** to the upper end of a packer mandrel **19**, on which is a body of packing material P (a rubber cylinder or frustum of a cone) adapted to seat and seal on the adjacent surface of a rat-hole drilled in the formation F, and at which level it is desired to take a specimen of the fluid issuing from the formation into the rat-hole, or pilot hole as it is sometimes called.

It will be seen that when the string of parts, above set forth, is lowered into the drilled hole until the packer takes its seat the packer then separates or seals off the liquid thereabove, if any, from that below the set packer P. Thus it will be possible to take a specimen of the fluid below the packer regardless of the fluid thereabove and outside of the hollow or tubular string.

A feature of this invention is to provide for taking a specimen of the formation product or other well fluid at the lowest practical portion of the testing string, and from the lowest portion of the well hole, or water pocket in a cement testing job. To that purpose there is screwed to the packer mandrel **19** a lower series of parts including a coupling **20** to which there is attached a lower by-pass tube **21** having lateral flow ports **22** which communicate through the string elements with the controlled ports **14** of the nipple **13**.

To the tube **21** there is attached a valve body **23** having a free check valve element **24** automatically closing downward by gravity and under pressure of fluid thereabove.

To the valve body **23** is attached a barrel section **25** of desired length, and to this is added a foot valve body **26** having a downwardly closing, gravity check valve **27** to which fluid may flow upward from the contiguous foot screen **28** at the end of testing or specimen taking portion of the string below the packer P.

It will be seen that when the packer P has been lowered and set at the desired level, in a given testing job, all of the tubular string sections below the swivel joint **6** will be held against rotation because of the friction of the packer on the engaged surface but the rigidly coupled sections upward from and connected to joint **6** may be freely rotated on and as to joint section **10** and its swivel core **8**.

Means are provided whereby the string portion extending upward from the swivel joint **6—8** may be positively closed, prior to letting the test string down or as it is being lowered, as may be preferred, to prevent the rise of well fluid therethrough until and after the adopted and attached packer has been seated or set to seal off at the desired level. This excludes the entrance of the well fluid to the tubular string while it is being lowered, as taught by Franklin, supra.

This means includes a test-flow valve which may be opened at will after the packer has been set so that unbalanced hydrostatic or otherwise caused pressure will result in an inflow and upflow of the fluid surrounding the introduced trapping barrel **25** on the bottom of the test string. Thus the test-flow valve controls the admission of the specimen fluid at the check valves **24—27** of the barrel but has no effect on their

closing action, since they are of the self-closing type.

The test-flow valve here shown includes a hollow body **30** whose upper end is adapted to close on the valve seat **3** and is provided with a series of upper, outlet ports **31** from its bore **32**. The valve **30** is splined at **30a** in the elongated shell **4** and is internally threaded at **33** to receive a screw stem **34** of the swivel core **8**.

The core **8** has a shoulder **8a** suspended on the upper end of the bushing section **6** of the swivel joint and forming a hitch coupling with the upper string parts attached to section **6**.

The core **8** is provided with an upwardly extending, tubular neck consisting of the stem **34** and an attached tubular part **35** whose upper end forms a seat for a complementary portion **36**, here a ball, fixed in the head of the valve body **30**; the ball being adapted to close down on the seat part **35** and thus close off the axial bore of the testing string from that point downward.

It will be seen that the valve **30** is functionally double acting; it may be closed on the seat part **35** and stop flow to the ports **31**, up or down, or it may be moved upward by continued rotation, in the same direction, of the upper string above the joint ring **7**, until it rests on the seat **3**, and have the same result of stopping flow through the bore of the valve body **30**, in either direction.

The screw thread **34** is of the left-hand pitch as it is preferred that the drill or testing string, above the swivel joint **7**, may be turned in the usual right hand direction when it is desired first to open the valve part **36** from its seat **35** and allow flow upward at the valve ports **31**, and then, by further turn of the rotative string section, above joint **7**, to close the valve body **30** on its superjacent seat **3**.

When a test is to be made at a level in a hole or well below the adopted packer P the lower assemblage is made up and the test-flow valve **30** is adjusted so that the ball **36** seats on and closes part **35** of the flow neck of core **8** and will prevent upward flow of fluid at the valve ports **31**. The packer is then lowered by and with the string to the desired level and is set to effect a sealing off or separation of the fluid above the packer from that below it; the fluid having been excluded from rising in the string past the closed valve ball **36**. The string portion above the telescoping, equalizing nipple **13** is now further lowered so as to close the ports **14** through which well fluid has equalized itself as the subjacent, test barrel portion of the string has advanced in the well liquid if any is present.

The automatic valves **24—27** will open freely to by-pass fluid to the ports **14** while the barrel and packer are introduced into the fluid which may be standing in the well hole, though none may pass the closed valve part **36**, which insures the lowering of the upper string in an empty state (note Franklin, supra).

While the test-flow valve may now be shifted up by right hand turn of the shell **5**, in which it is splined, to open the hollow seat part **35** to the low pressure or empty string bore thereabove to permit an inflow of the superior pressure of the fluid, if any, below the packer into the barrel **25**, it is preferred to connect a head appliance to the upper end of the string S before opening the test-flow valve (**36**) in order that the apparatus and the well or hole may be protected against a sudden rise in well pressure and against an undesired and injurious rate of flow of formation fluids and entrained solids.

A feature of the invention, therefore, is the provision of a safety and controlling means at the head of the string and the provision of a swivel between the testing string and the applied head appliance so that the upper string portion, that is above the test section joint **10**, may be rotated to effect opening of the test-flow valve **30—36** to permit upflow of fluid of unbalanced pressure to the specimen barrel **25** and to higher level in the string if desired.

The head appliance, as here shown, includes a fitting **40**, such as a suitable casing head, having control valve **41** to provide for flow of high pressure fluid, as from a circulating pump (not shown), to kill the well if this expediency should arise after the test-flow valve part **36** is opened. The casing head is also provided with flow line control valves **42** by which flow from the well may be perfectly controlled through the test string should it be desired to permit the well to flow therethrough.

Therefore, as soon as the testing string has been lowered and the packer P set to seal off upper and lower strata of fluid thereat and the by-pass joint ports **14** closed by the lowering of the thereabove string portion, the desired head appliance is brought to position and attached to the now set string before the test-flow valve part **36** is opened so that full control of the apparatus is had and the safety of the well hole is provided for.

A suitable head-swivel joint J, Fig. 2, is introduced between the top section of the string S and the casing head **40**. As here shown, this head swivel includes a pin section **45** having a stem **46** turning in a bushing **47** which is screwed at **48** to a tubular housing **49** to which the casing head **40** is suitably attached. On the upper end of the bushing rests an antifriction bearing **50** engaging a retaining collar **51** screwed on the upper end of the stem **46** and forming a connection between the stem **46** and the bushing **47**, and swivelling with the stem parts in the housing.

Fixed to the stem **46** is a tubular extension **52** which turns in the bore of the housing **49** and carries a set of packing cups **53** to prevent fluid leak running back to the working surfaces of the swivel parts **46—47**. The rings are adjustably retained by a crown nut **54** screwed onto the upper end of the shank **52**.

The collar **51** is fixed against accidental unscrewing by a set screw **51a** engaging the shank **52** which is here shown as screwed at **52a** onto the stem **46**.

In Fig. 3 there is shown a conventional form of casing packer CP having a set of toothed slips **60** attached to a sliding ring **61** having a hook **62** engaging a pin **63** on the packer mandrel **64**. When the pin carrying mandrel is turned to disengage the pin from the hook **62** a set of bow springs **65** frictionally engages the near casing bore face (not shown) and holds the slip ring **61** from turning. Then the string section **66** is lowered and an expanding cone **67** moves down and thrusts the slips **60** outward to bind into the casing. At the same time a packing sleeve **68** of rubber or other suitable material is expanded by pressure between an upper pressure part **69** and its base rest **70**, in the well known action of such packers.

It is understood that this casing packer CP will be introduced into the string between the by-pass nipple **21** and the joint section **15** of the

string when a test is to be made of a water string of casing cemented in a well hole. It is therefore understood that a packer best adapted for the given test job may be adopted and incorporated in the string, within the scope of this invention.

The method, in its several steps is as follows: the string parts, as above described, are assembled with the specimen barrel **25** below the incorporated packer, as P, and the test-flow valve element is closed on its lower seat **35** to prevent upflow of well fluid to the thereabove string parts. The string is now built section by section in the usual manner and lowered into the well hole, through the circulating or other fluid that may be present and its bore is kept dry or empty by the closed valve **30** on seat **35**, until the packer is located at the desired level where it is then set on formation, or in the cemented casing (as the case may be) to seal off the upper and lower strata, thereat, of well fluid, whatever its nature may be. This positions the bottom, trapping barrel **25**, with its self-closing or check valves **24—27**, at the level from which it is intended to take a specimen of the fluid that may be issuing from the naked formation about the barrel, or that may be leaking past the cemented end of a water string of set casing as in a water shut-off test job.

After setting the packer, the string is lowered to close the by-pass ports **14**, which, while open during the lowering of the string, provide for equalization and upflow of well fluid (gas, oil or formation water, or fluid from without a cemented casing) passing into and up from the immersed barrel, and up in the string parts to the closed valve on seat **35**. The valve **30** is now opened from the seat **35** by turning the upper string, above ring **7** to the right. This allows the unbalanced fluid, if any, from below the packer P (or its substitute) to flow into the trapping barrel **25** and displace other liquid which may have collected therein due to free equalization while the by-pass ports **14** were open, and allows the fluid to rise in the string bore to a height of equalization, or possibly flow at the head.

In making the test the valve part **36** will be kept open, the body **30** in neutral position between its two seats **36** and **3**, for a period determined by conditions and at least until the fluid issuing from the formation (in formation testing) will have ample time in which to collect in the specimen barrel **25**, and, preferably, to have flowed up into the string bore above the test-flow valve **30**, thus taking another volume of formation fluid, separate from that trapped in the barrel **25** between the self-closing valves **23—27**.

The testing string or tool may now be pulled or drawn from the well hole, if desired with the test-flow valve part **36** still open from its seat **35**. This will result in a "dry pulling" job since any liquid standing in the bore of the string, and apart from that trapped in the barrel, will freely drain downward and out at the open by-pass ports **14** and **22** as they rise in the well; the ports **14** being mechanically opened by the pull on the upper string in the effort to draw the set packer P, or to lift the string portion attached to the nipple **13** by the hitch shoulder **17**. To take a well specimen, without loss and of substantially uncontaminated nature, in "a dry job operation" is one of the important advances of this invention over the prior art. A dry job in the extraction of a string from a well greatly facilitates the whole operation.

But if it is desired to trap and examine such fluid as may be permitted to rise in the tool string above the test-flow valve **30** the operator now turns the rotary string portion above the swivel **7** to the right once more and thus moves the top of the valve **30** onto seat **3**, thus trapping the fluid thereabove, also, also without any effect on the specimen in the barrel **25**. The string may now be pulled and both specimens separately preserved for examination and log record. If the fluid has risen to much height in the string above the closed valve **30**, the pulling of the string will be a "wet" job to that extent.

It will be seen that after the packer, whatever its type, is set in readiness for the test, the valve part **36** becomes the controlling means for the admission of the well fluid to the barrel under unbalanced pressure as the valve is opened to permit flow to the empty bore of the string portion above the valve **30**.

In oil or gas well fields where the pressures are expected to be high, the operator shifts the head appliance **40** into place and connects up the swivel joint J, the string S, and the head appliance, with its valves **41—42** closed, before he opens the test-flow valve part **36** from its seat **35**, after the testing string has been set in the well hole and the by-pass **14** closed. Thus he has the well under full control and now may open the valve part **36** to unbalance the pressure of the formation, or other, fluid below the set packer, and at the same time opening the head appliance flow line valve **42**. Should undue flow develop from the well he may close the valve **42** and so hold back flow at the open valve part **36** down in the string without having to turn the string to close or reduce the opening at the test-flow valve part **36**.

In necessity, the well may be killed by opening the pump line valve **41** and driving fluid down the test string while the valve **30—36** is in open position from its dual seats **3—35**.

The term "well fluid" is intended to apply to either formation product, that is fluids coming into the hole from the natural formation, or to fluid leaking into a cemented casing, for water shut-off tests.

What is claimed is:

1. A well testing tool having a tubular string with a formation or casing packer, a specimen barrel having self-closing valve means to trap well fluid, and said string having above said means a test-flow valve for closing the string thereabove so that it may be lowered into the well hole empty and being openable for permitting inflow of well fluid to the barrel under its own pressure from below the set packer to the empty string above the valve; said trapping means operative to hold a specimen while the string is being drawn with the flow valve open to drain the string above the trapping means.

2. A tool as set forth in claim 1, and in which the specimen barrel is arranged below the packer.

3. A well testing tool having a tubular string including a well fluid packer, a specimen barrel, means for admitting well fluid to the barrel and trapping it against loss by draining as the string is drawn from the well, and valve means in the string above the barrel and its trapping means for closing or opening the string thereabove so that it may be lowered empty or drawn empty.

4. A well testing tool including a tubular string, a packing means carried by the string to seal off the well at a level above the foot of the string, a valve in the string to close it against fluid inflow to the string portion thereabove so

that the string may be lowered empty into the well, and a specimen trapping valved, barrel means below said valve whereby to retain a well fluid specimen when the string is pulled with said valve either closed or open in the string.

5. A tool as set forth in claim 4, and having, in combination, a stationary, valved head works having a swivel connection with a portion of the said string whereby the latter may be turned to open the string valve for potential flow of well fluid to the head works under control of the head valves so that the testing tool may be left in situ while the well is in production, if desired.

6. A well testing tool including a string of tubiform sections having a packer to seal off the well hole at a desired level, a master valve in the string to close it against inflow so that the string may be lowered empty and for opening the string after the packer is seated, and an automatic specimen means including a barrel having upper and lower valve devices below said valve whereby to receive and retain a specimen, when the string is pulled, whether the valve is in open or in closed position.

7. A well testing string having an appropriate packer, a shut-off valve, and specimen trapping means arranged below the valve and operative to receive a well specimen and to retain it, as the string is pulled, with said valve in either closed or open position, said means including a barrel having vertically spaced check valves.

8. A well testing string including means to seal off fluid at a given level in the well hole, specimen trapping means in the string for taking a specimen from below the set packer, and valve means in the string and above the trapping means, for closing the string to keep it dry while it is being lowered into the well hole and for opening communication from the space below the set packer through said trapping means to the empty string portion above the valve; said trapping means holding its specimen while the string is pulled with the said valve in open or in closed position and means to by-pass fluid from the string to the well hole below the packer.

9. A well testing string including a fluid packer, to seal off at a given level, means to trap a specimen of fluid from below the set packer, and a test-flow valve above said means for closing the string against upflow until the packer is set and for controlling fluid admission from below the packer to said means and for draining the string while it is being pulled with the specimen; said valve having two spaced seats from one to the other of which it is movable by a unidirectional rotation of the string portion above the set packer.

10. A well testing tool including a tubular string having a packer, barrel means having self-closing foot valve to automatically trap a well specimen from below the seated packer, and valve means for selectively closing the string above the trapping means to lower the string dry, or for opening the seated string for upflow of well fluid, and for opening or closing the string, as it is to be pulled, without loss of the specimen in said trapping means.

11. A tester as set forth in claim 10, and in which the valve means operates to carry a possible second specimen if the valve is closed when the string is to be pulled and after a first specimen has been entrapped in said automatic means and a by-pass device between the said trap means and the said valve means.

12. Deep well testing apparatus having, in combination, a string of tubular elements, including a well fluid shut-off packer, a foot barrel attached to the string and having up-flow check valves in vertically spaced relation for trapping a well specimen after the packer is seated, and means for closing the string above the trapping means for dry lowering of the string or opening the seated string for upflow of well fluid, and for opening or closing the string, when it is to be pulled, without loss of the trapped specimen.

13. Apparatus as set forth in claim 12, and including a by-pass between the packer and said valve for static pressure equalization.

14. A well testing tool as set forth in claim 1, and in which a portion of the string is rotative and is operatively connected to the test flow valve to open or close it after the packer is seated, and a well head appliance including a swivel connection with the rotary string part and having control valves for controlling fluid flow from the string after the test flow valve has been opened by operation of the said swivel connection.

15. A well testing tool having a tubular string with an appropriate packer adapted to be set at a desired level in the well hole, a shut-off valve in the string, and a specimen trapping means including a receptacle connected in the string below the said valve and adapted to receive a well specimen and to retain it, as the string is pulled, with said valve in either closed or open position, and a by-pass to drain the string when the valve is opened without affecting the trapped specimen in said receptacle.

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